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THE EFFECT OF MONOLITHIC PUMPED PACKING ON VENTILATION AND STRATA CONTROL AT LINGAN COLLIERY, NOVA SCOTIA

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THE EFFECT OF MONOLITHIC PUMPED PACKING ON VENTILATION AND STRATA CONTROL AT LINGAN COLLIERY, NOVA SCOTIA

by

A.W. Stokes* and P. Cain*

ABSTRACT

Gob leakage is a serious operational problem in the Cape Breton Development Corporation's longwall coal mines. Leakages in excess of 70 percent have been recorded in walls less than 1000 m long, causing production delays through excessively high methane levels at the return face end.

In an attempt to reduce air leakage a monolithic packing system was installed in the 9E District at Lingan Colliery. The performance of the new packing method was monitored by the CANMET Coal Research Laboratories. Ventilation surveys using sulphur hexaflouride tracer gas to quantify gob leakage and strata control investigations to monitor the effect of the packing methods on gateroad deformation were conducted before and after the packing change.

This paper describes the investigation programme and the effects of the packing change on air leakage and gateroad deformation in the 9E District.

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L'EFFET DU REMBLAYAGE MONOLITHIQUE SUR LA VENTILATION ET LE CONTRÔLE DES STRATES À LA HOUILLÈRE LINGAN EN NOUVELLE-ÉCOSSE

par

A.W. Stokes* et P. Cain*

RÉSUMÉ

Les fuites d'air dans les remblais constituent un grave problème opérationnel dans les mines de charbon exploitées par longues tailles de la Société de développement du Cap-Breton. On a enregistré des fuites d'air à plus de 70 % dans les murs de moins de 1 000 m de longueur. Ces fuites d'air occasionnent des délais dans la production en raison des niveaux excessivement élevés de méthane au front de taille de retour.

On a donc installé un système de remblayage monolithique dans la zone 9E de la houillère Lingan dans le but d'essayer de réduire les fuites d'air. Le rendement de cette nouvelle méthode de remblayage a été surveillé par les Laboratoires de recherche sur le charbon du CANMET. De plus, des études sur la ventilation à l'aide d'un gaz traceur à l'hexafluorure de soufre pour quantifier les fuites dans les remblais et des études sur le contrôle des strates pour surveiller l'effet des méthodes de remblayage sur la déformation de la voie de roulage ont été effectuées avant et après les changements apportés à la méthode de remblayage.

Le présent rapport décrit le programme de recherche ainsi que les effets du changement de méthode de remblayage sur les fuites d'air et la déformation de la voie de roulage dans la zone 9E.

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1. INTRODUCTION

The loss of large quantities of ventilating intake air to return airways by leakage through the longwall wastes has long been recognised as a problem at Lingan Colliery. The east side panels are particularly affected due to the presence of large sandstone bodies in the overlying strata. These sandstones have poorer caving characteristics than the mudstones and siltstones overlying the west side panels (Figure 1) resulting in less well compacted wastes (1).

Production scheduling at the colliery in 1984 required the operation of two adjacent longwall faces, 8E and 9E, which precluded the use of the most effective leakage control method previously used, 'cundy ventilation' (Figure 2). In an effort to prevent gob leakage and to allow safe and efficient production from both active east side panels, the Cape Breton Development Corporation (CBDC) decided to implement a monolithic pumped packing trial on the 9E Maingate and asked the CANMET Cape Breton Coal Research Laboratory (CBCRL) to monitor the effect of the packing change on both ventilation and strata control.

The monolithic packing method selected was 'Astrapack', manufactured by Pozament U.K. Ltd. A major factor in the selection of this method was the smaller quantity of imported material required than either 'Aquapack', which had been tried earlier in the coalfield, or 'Tekpack', a similar product produced by Foseco Ltd. Monolithic packing commenced after the 9E Faceline had advanced 617 m. The 'Astrabent' component of the system is mixed and pumped from a station located outbye, close to the access deeps. The 'Astracem' component is mixed and pumped from a station mounted over the stageloader at the face end. The pack shutter was manufactured at the pit to an NCB design, and the packing bags are made locally. A 2.1 m wide pack 2.1 m high is put on in 1.5 m increments, replacing a 1.75 m by 1.75 m hardwood chock and a ventilation seal made by stacking stonedust bags in the pack during construction (Figure 3).

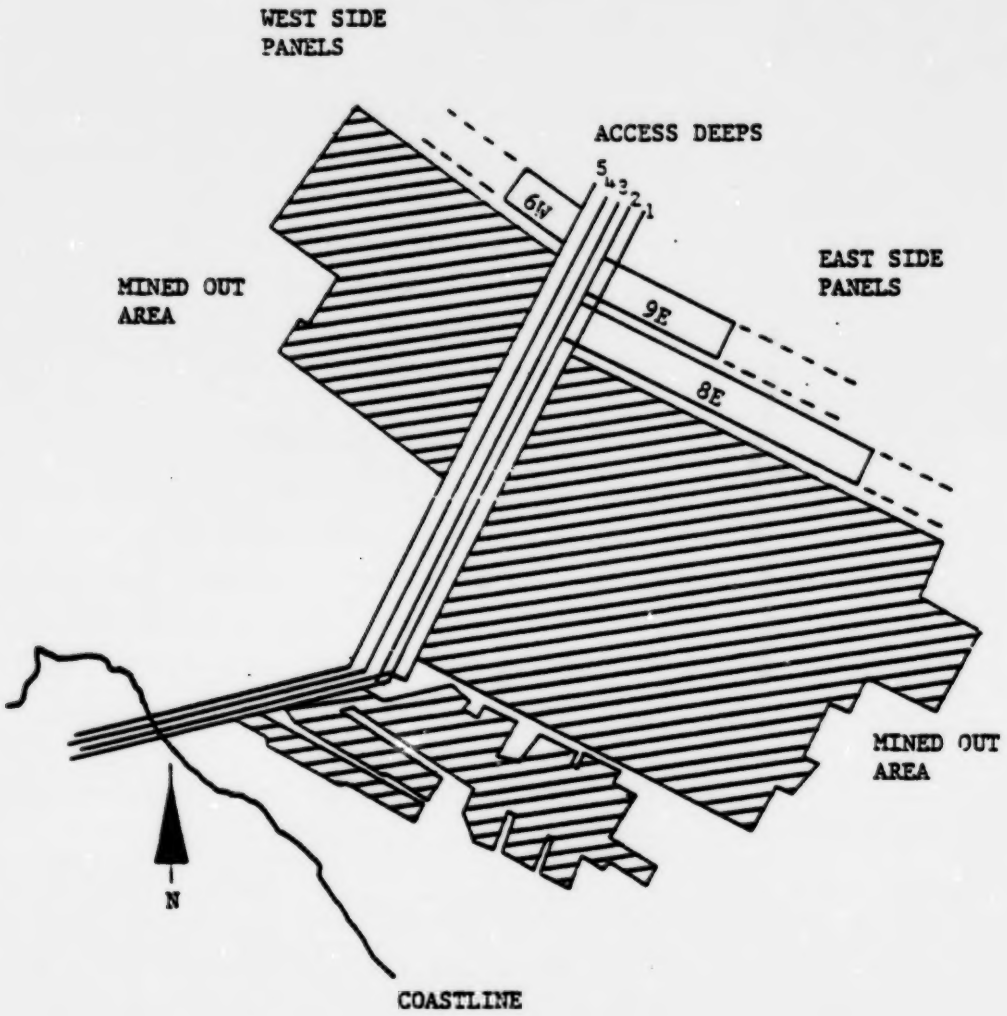


Figure 1 - Lingan Colliery, New Waterford, Nova Scotia

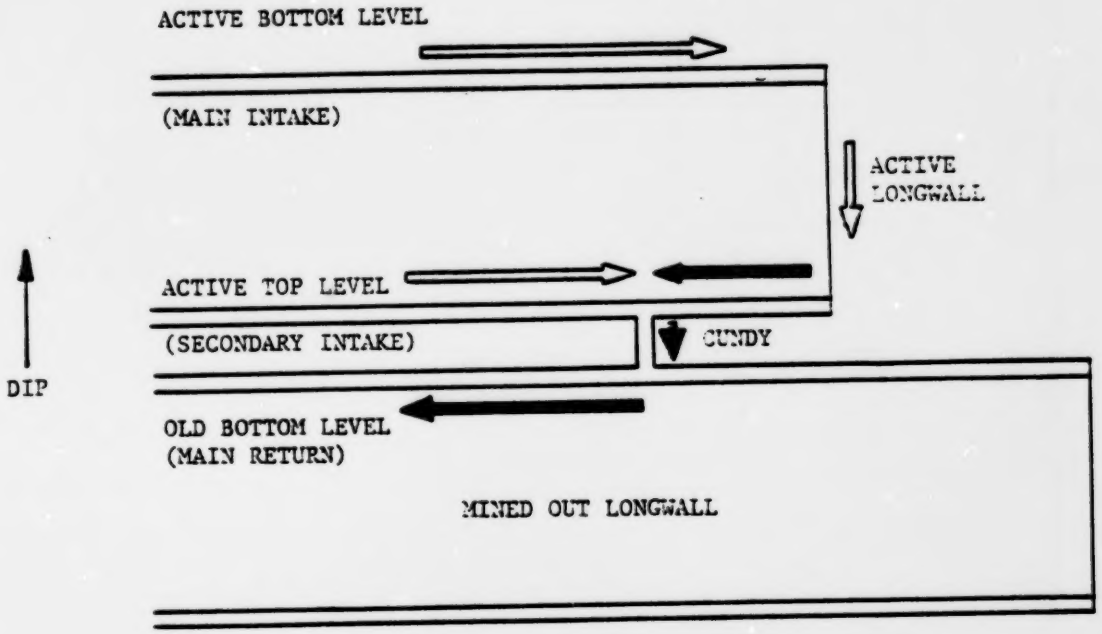


Figure 2 - 'Cundy ventilation' as practised at Lingan Colliery

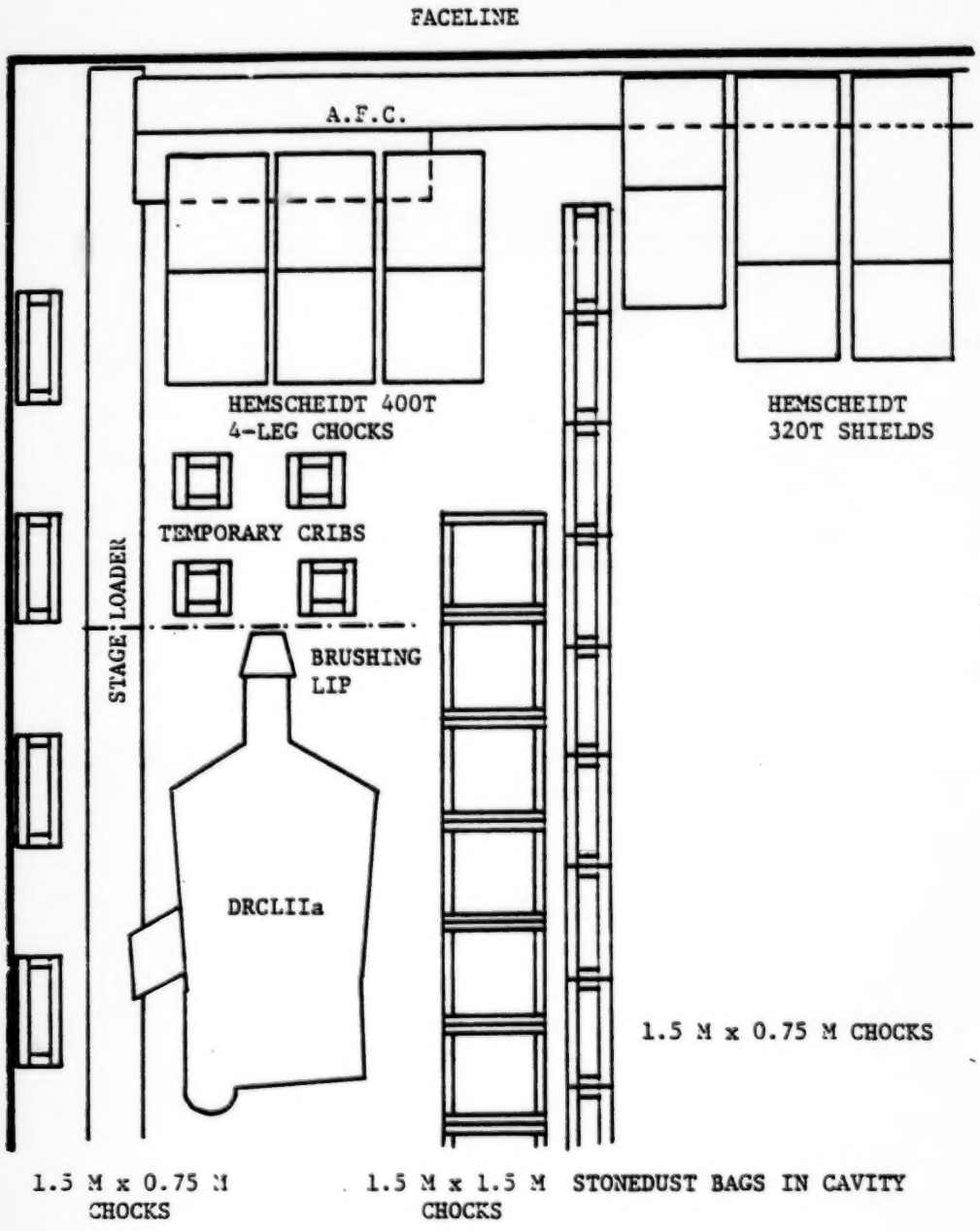


Figure 3 - Maingate support in the 9E Maingate prior to the implementation of monolithic packing

This report describes the investigations carried out by CBCRL in the 9E District and the effect of the packing change on ventilation and gateroad deformation.

2. INVESTIGATIONS IN THE 9E DISTRICT

The change in packing method in the 9E Maingate resulted in a 119% increase in packing costs. The cost of the 1.75 m x 1.75 m wooden chock illustrated in Figure 3 was $420 for each linear metre of gateroad, compared with $920 a metre for the monolithic pack that replaced it (costs given are for materials alone). Naturally, CBDC were concerned that this increase in cost should be justified by improved gob sealing and no deterioration in gateroad conditions. Investigations to determine the effect of the packing change were planned and carried out by CBCRL at the request of CBDC. Strata control and ventilation programmes were conducted in both the conventionally packed and pump packed sections of gateroad.

2.1 DISTRICT DETAILS

The 9E Panel at Lingan Colliery (Figure 1) is a 217 m wide advancing longwall in the 2.1 m thick Harbour Seam. Protected from the adjacent 8E Panel by a 76 m wide barrier pillar, the 9E Face lies beneath 550-610 m of cover and has a planned advance of 2600 m. Working along the strike, the face is supported by Hemscheidt 320 tonne two-leg shields and coal is cut by an AM300 double ended ranging drum shearer. An average weekly face advance of 18 m gives a weekly saleable output of 12,750 tonnes, coaling on two shifts.

The face end layout in the 9E Maingate is shown in Figure 3. The arched roadway profile is cut using a Dosco DRCL MKIIa, which maintains the rip 7-14 m behind the faceline. Two piece 120 mm x 90 mm 'I' section steel arches weighing 29.5 kg/m are installed at 0.9 m intervals, wraparound fishplates are used and the arches are strutted and lagged.

Prior to the implementation of monolithic packing, the maingate pack consisted of a continuous row of 1.75 m x 1.75 m, 80% solid hardwood chocks adjacent to the arch. On the gob side of this was a 30 cm wide wall of stonedust in 25 kg bags and a 0.75 m x 1.75 m skeleton hardwood crib built just behind the panline. Intermittent 1.5 m x 0.75 m skeleton wood chocks were also built on the ribside where the coal is extracted to a distance of approximately 1.5 m below the ribside leg of the arch. The pack was usually built midway between the face and the ripping lip, a distance of approximately 6-12 m.

The monolithic pumped pack replaced the 1.75 m x 1.75 m hardwood chock and the stonedust bags. All other support details remained the same.

Roof and floor lithologies in the 9E Maingate have been mapped by CBDC geologists. No cored boreholes have been drilled, but a methane drainage borehole in the 9E Tailgate was logged. Roof strata comprise freshwater siltstones and mudstones containing braided sandstone channels and overbank deposits represented by laminites and occasional sandy limestones. Floor strata comprise a 5-15 cm siltstone seatearth underlain by a strong shale.

2.2 STRATA MECHANICS INVESTIGATIONS

Strata control monitoring consisted of detailed site monitoring (one site in the conventionally packed section, two in the pumped pack section) and gateroad deformation surveys, described below.

2.2.1 Site Monitoring

Three detailed investigation sites were installed after 504, 702 and 891 m of face advance, at arches 560, 780 and 990. Pump packing commenced after 620 m advance, at arch 710. Each investigation site was instrumented with pack load cells and pack closure meters. Rock bolts were also installed to measure gateroad closure. Monitoring frequency was initially daily, reducing in frequency as the face moved away from the site. Details of the instrumentaion installed at each

site can be found in Table 1. Details of the roof lithologies at each site were also recorded, and are illustrated in Figure 4. Relative locations of gateroad and pack instrumentation at each site are also shown in Figure 4.

Table 1 - Instrumentation used in the investigation programme

Parameter	Instrumentation
Closure: Gateroad	- Rock bolts in roof and floor.
Closure: Packs	- Electronic resistance pack strut (Model Cor/P-R, Roctest Inc., Montreal).
Load: Packs	- Earth pressure cell, hydraulic readout 0-1000 psi (Solinst Canada Ltd., Burlington).
Differential Strata Movement	- Irad Gage Flexible Sonic Probe (Solinst Canada Ltd., Burlington)

2.2.2 Gateroad Deformation Surveys

So that a broader picture of gateroad deformation could be obtained and related to factors other than the packing method (e.g. rate of face advance and roof geology), gateroad height surveys were carried out with the face at arch 1041 and arch 1530. Heights were measured from the arch crown to the floor at 9 m (10 arch) intervals.

2.3 VENTILATION SURVEY

2.3.1 Ventilation Investigation Technique

Eight ventilation surveys were conducted on 9E Longwall; the first after a wall advance of 400 m and the last after 1300 m advance. These surveys were designed to determine the magnitude of the air leakage through the gob with the different packing systems. In addition, the flow paths through the gob were defined by injecting SF_6

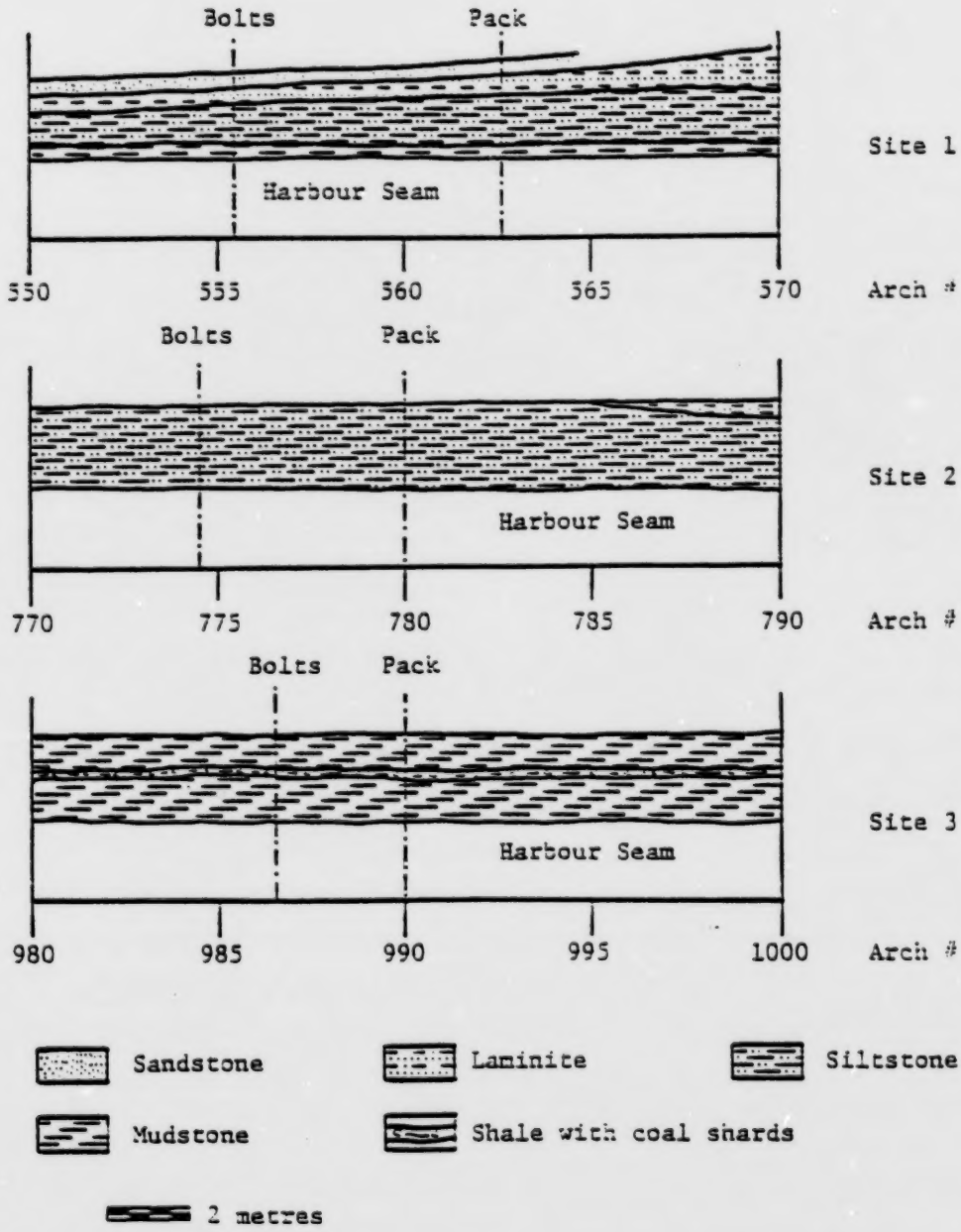


Figure 4 - Location of investigation sites and details of roof lithologies, 9E Maingate

from the intake and locating its point of emergence into the return. From a series of these injections it was determined that the leakage flow was virtually parallel to the faceline except in the area immediately behind the face.

The ventilation surveys consisted of measuring the airflow at, and pressure drops between, a number of measuring stations throughout the district. These were sited 50 m apart along the two gateroads starting from two primary stations located at the face startline. Additional stations were created for each survey to take into account the face advance. For each measuring station in the intake gateroad, there was a corresponding one in the return, forming an integrated network of points throughout the district.

Initially vane anemometers were used to measure the air velocity at each station. These values were used with photographically determined station cross-sectional areas to calculate the air quantities. However, the results showed that it was difficult to get airflow measurements to better than plus or minus 15 percent using this method. The measurement error tended to mask the air leakage profiles. To overcome this problem a new, more accurate technique was developed. Sulphur hexafluoride (SF_6) was released into the airstream near the tailgate end of the face at a continuous steady rate. Samples of air were collected in one litre tedlar gas sampling bags from each survey station along the return gateroad. An integrated air sample was collected from the entire roadway cross-section traversing with a sampling probe in the same manner that an anemometer is used in making a conventional airflow measurement. In this way the air samples contained the average concentrations of SF_6 at each station and negated the effects of a non-uniform distribution in the airstream.

The air quantity flowing at each return gateroad station was found from the SF_6 concentration in the bag samples. These values were used in the following relationship:

$$Q = \frac{\dot{v}}{c}$$

Q is airflow ($m^3.s^{-1}$)

$\dot{v}$ is volume flow of SF_6 ($m^3.s^{-1}$)

c is the SF_6 concentration

As the leakage paths through the gob were determined by the gob injections, no airflow measurement in the intake gateroad were required.

2.3.2 Method of Analysis

The SF_6 concentrations in the tedlar bags were determined by analysis back in the laboratory. A gas chromatograph utilising an electron capture detector was used. This can measure trace concentrations of SF_6 in air as low as a few parts per trillion.

2.3.3 Treatment of the Results

As the major air leakage paths were almost parallel to the faceline, the gob area was divided into a series of 50 m wide corridors, each orientated parallel to the faceline as shown in Figure 5. It is assumed that the leakage airflow through the gob remained confined to the corridors and did not drift from one to another, therefore the resistance of each corridor can be determined using a variation of Atkinson's equations (2). A comparison of the gob corridor resistances was one method used to assess the effectiveness of the monolithic packing. From previous surveys conducted in other districts (8E, 4W), average values for the resistance of gob corridors with a conventional wooden gateside pack was already known (3). These provided standards against which any increase in gob corridor resistance due to the monolithic packing could be measured.

An advantage in using the gob corridor layout is that it lends itself to computerised network analysis. A ventilation modelling program was used to simulate the airflows that would have been obtained in 9E if conventional wooden packs or the monolithic packs had been used for its entire length.

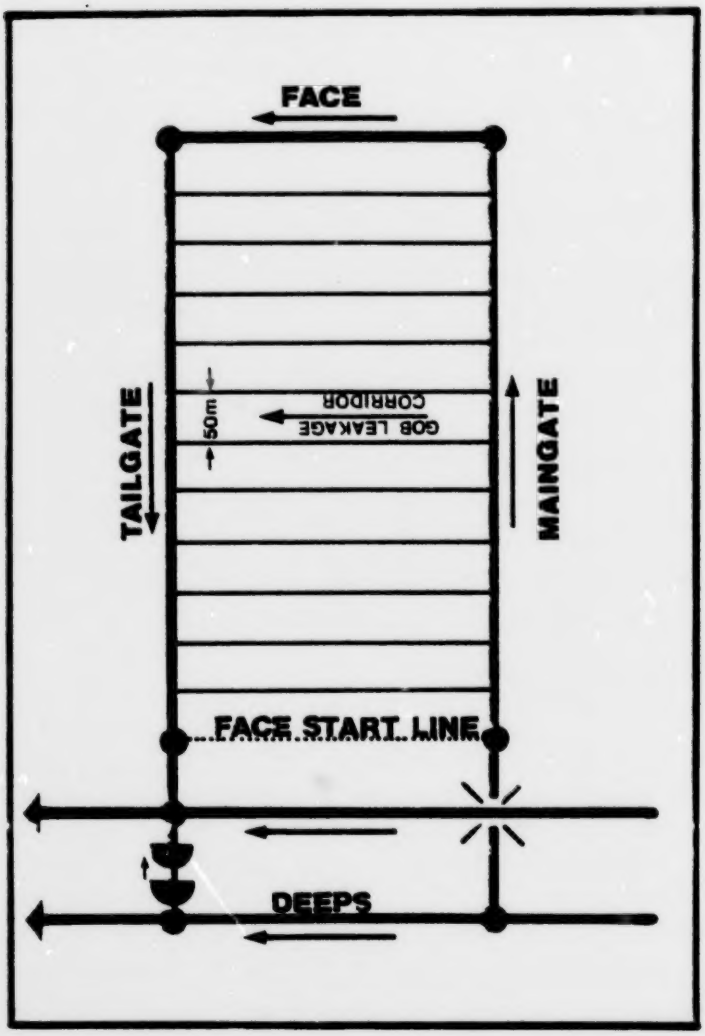


Figure 5 - Layout of gob corridors

From these results airflow profiles along the length of the return gateroad were generated (simply a graph of the percentage of the district intake airflow measured in the tailgate versus the linear distance from the face startline). Profiles obtained directly from the ventilation surveys were compared with these to assess the improvement in gob leakage effected by the monolithic packing.

3. INVESTIGATION RESULTS

3.1 STRATA CONTROL

3.1.1 Site Monitoring

Convergence and pack load data collected during the investigation were smoothed and adjusted for differences in location relative to the coalface at the time of installation. Rock bolts installed to measure gateroad closure were tampered with at Site 2 and so yielded no data. Pack and gateroad closure results are illustrated in Figure 6. Pack load results are shown in Figure 7.

3.1.2 Gateroad Deformation Surveys

Gateroad height profiles obtained from the two deformation surveys are shown in Figure 8. Pack type, rate of face advance and roadway geology are also represented.

3.2 Ventilation

The ventilation surveys provided a method for evaluating the monolithic packing. In addition, the surveys also recorded improvements and deteriorations in the gob leakage due to other sealant methods employed (lining the first 400 m of the intake with shotcrete) and a change in the gobside packing used in the tailgate.

Figure 9 shows the predicted airflow profiles for the conventional and monolithic packing and the measured profile from the last survey

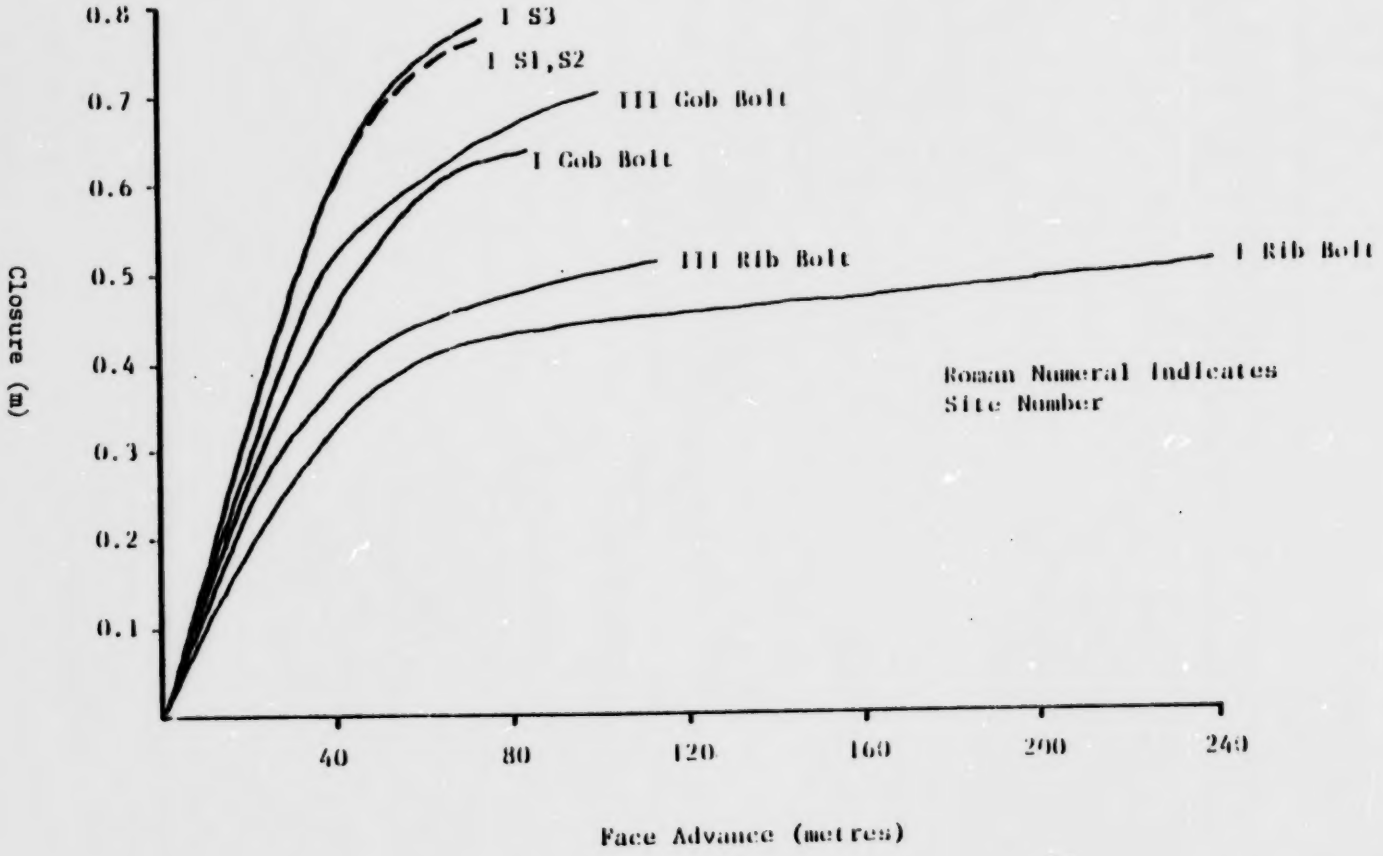


Figure 6 - Adjusted closure results, 9E Maingate

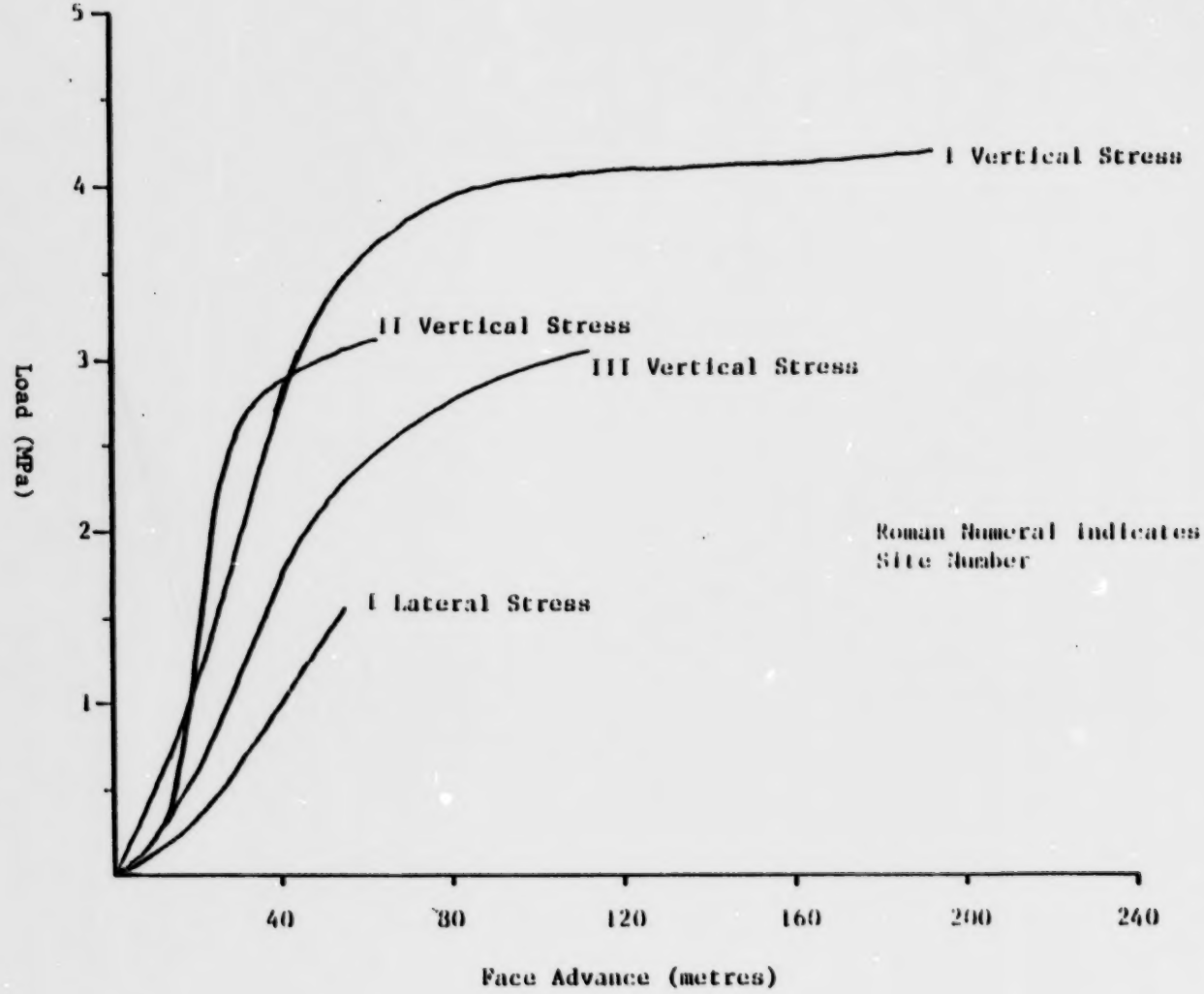
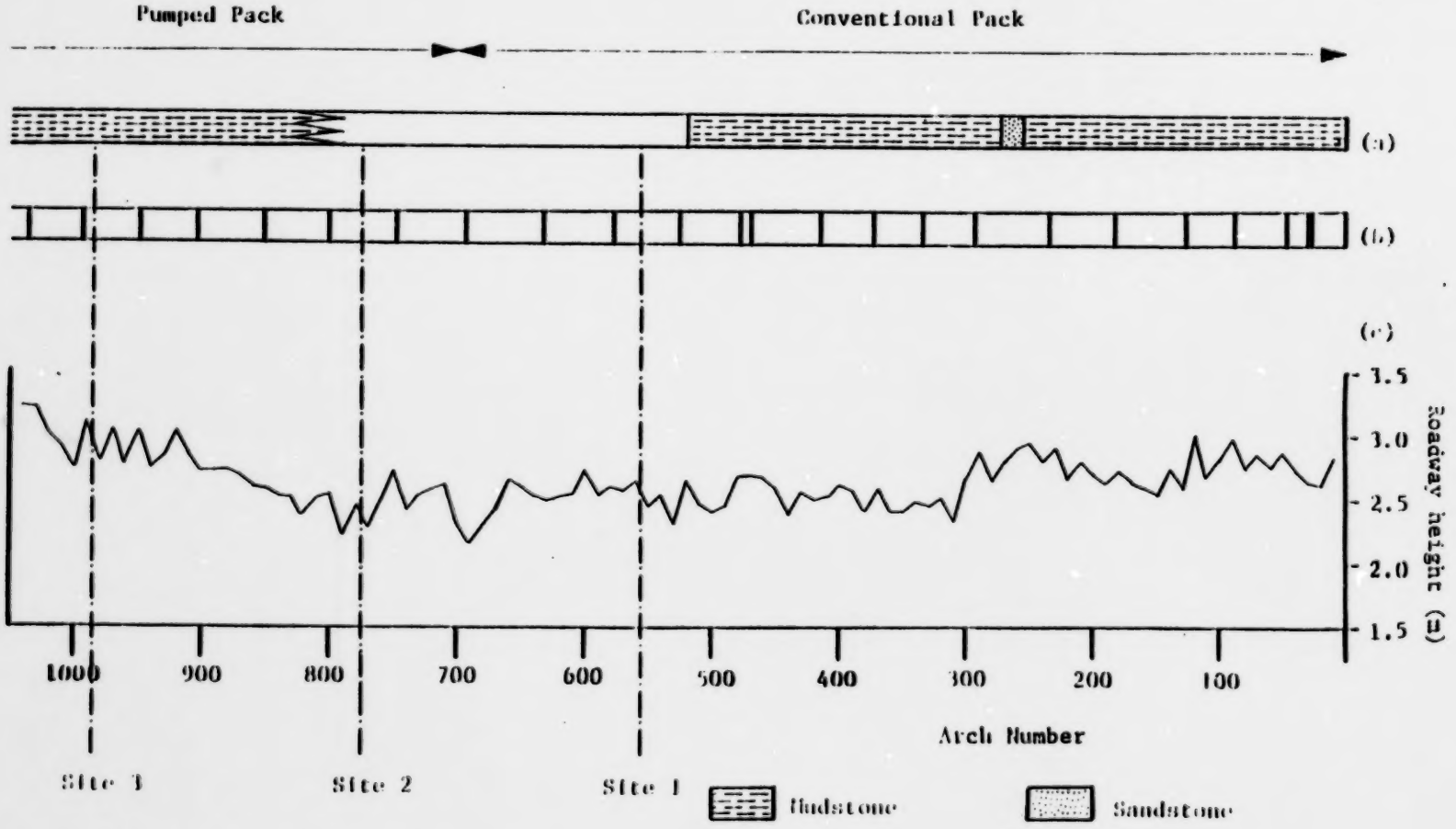


Figure 7 - Adjusted load results, 9E Maingate



a) Generalised roadway geology

b) Face advance in two week increments

c) Roadway height (last arch 1041)

Figure 8 - Location of investigation sites in the 9E Maingate with respect to roof geology and face advance and showing gateroad height profile

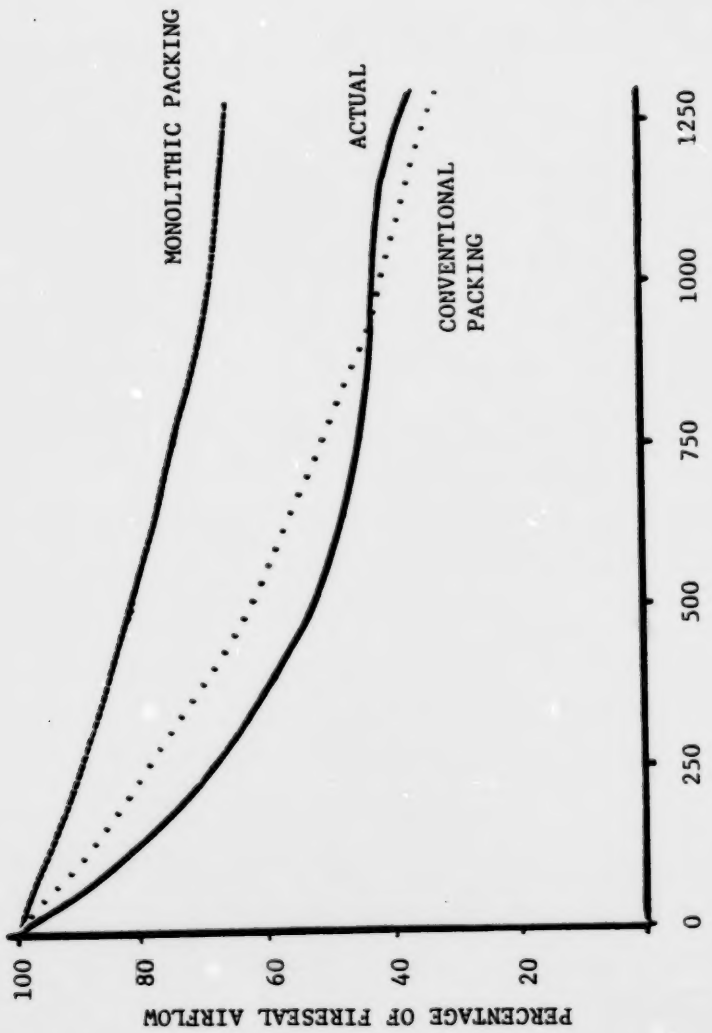


Figure 9 - Measured and predicted airflow profiles for 9E

completed in January 1986. Figure 10 shows earlier profiles measured before during and after shotcrete was sprayed along the first 400 m of intake gateroad. Lastly, Figure 11 shows a comparison of the gob corridor resistances measured in 8E, 9E and 4W.

4. DISCUSSION

4.1 STRATA CONTROL

The information given above reveals only two marked differences between investigation sites; the roof geology and the method of packing. Sites 1 and 2 are directly comparable, being in the same geological setting and differing only in packing method. However, the absence of closure data for Site 2 makes detailed comparison impossible. Pack load data for Site 2 reveals a more rapid load development there compared with the other sites. In the absence of closure data, this is difficult to evaluate, but it could be due to several factors acting singly or in combination:

a) a higher cement content in the Site 2 pack, giving a more rapid strength development in the early stages,
b) closures at Site 2 immediately behind the faceline due to the stronger roof strata, allowing maximum strength and stiffness development in the pack prior to subsequent loading, and
c) less pack confinement on the gobside and roadside at Site 3.

Closure results at Sites 1 and 3 indicate very little difference between the two sites, although convergence at Site 3 is marginally higher. Both the closure and load data indicate two phases of gateroad deformation. Phase 1 represents closure due to immediate extraction and face effects extending 60 m behind the faceline. Phase 2 represents a constant, time dependent deformation.

Pack loads at Sites 2 and 3 are lower than at Site 1. Since the only change in packing method was the replacement of the wood chock and stonedust wall by the monolithic pack, it can be assumed that loading

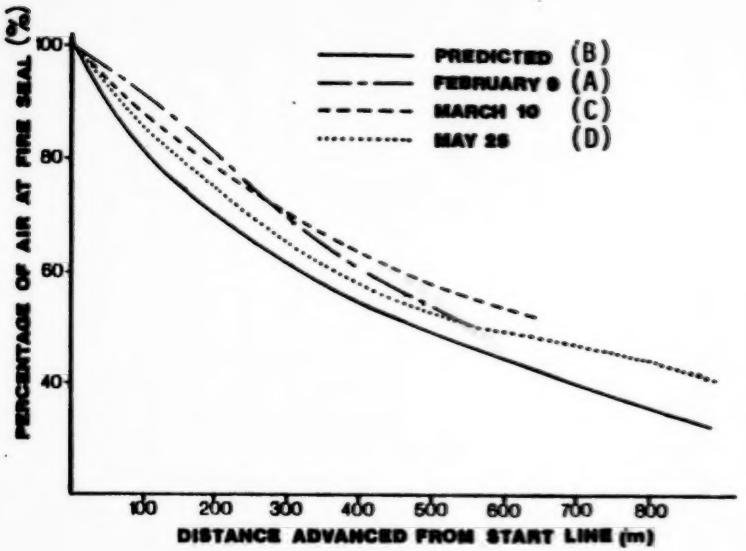


Figure 10 - The effect of shotcrete spraying in 9E Maingate

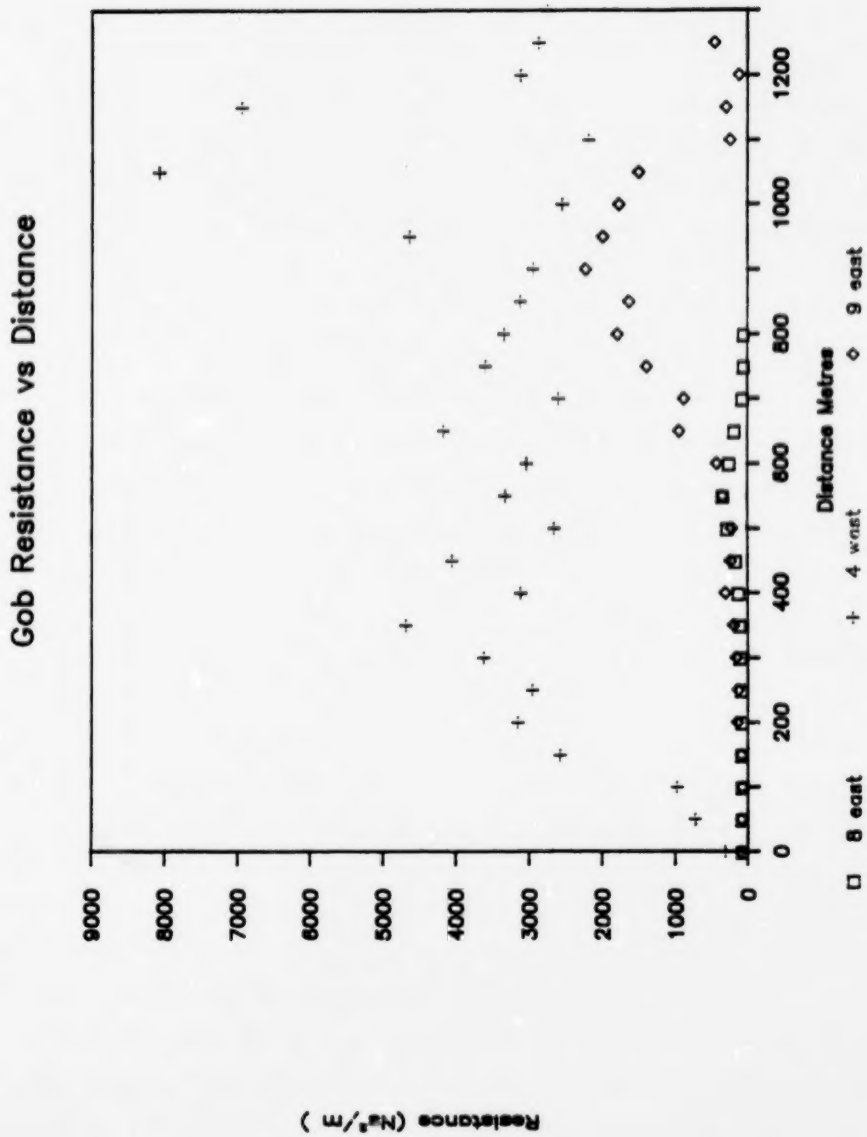


Figure 11 - Gob resistances in 9E, 3E and 4W

on other support elements was similar at all sites. A load of 4.2 MN/m^2 on a 1.75 m wide wooden element at Site 1 represents an element resistance of 6.3 MN per metre run of gateroad. A load of 3.1 MN/m^2 on the 2.1 m wide monolithic pack gives an element resistance of 6.6 MN per metre. Thus the monolithic pack provides approximately the same degree of support as the wooden pack it replaced.

Gateroad survey results also tend to agree with the conclusion that the stability of the gateroad has been maintained, but that closures will ultimately be less in the zone of mudstone roof and pumped pack. This is as yet unproven due to the proximity of the faceline to the roof geology transition point at the time of the survey. An additional observation is that the first 200 arches of face advance are subject to less closure, possibly due to bridging of the strata across the substantial pillars at this point and therefore resulting in incomplete gob compaction. This would result in higher ventilation losses in this area, a conclusion reflected in practice (see Figure 11). The maintenance of an efficient gob seal in this zone is therefore of utmost importance to the improvement of ventilation efficiency.

4.2 VENTILATION

A comparison of the predicted and measured profiles shown in Figure 9 clearly shows the effect of the monolthic packing. The monolithic packing extends from 620 m inbye of the face startline up to the face 1350 m inbye. Along this part of the return gateroad the amount of leakage from the gob was considerably reduced. This is shown by the flatter profile compared to the predicted curve for the conventional packing system. By improving the seal on the inbye section of the face, the leakage through the first 600 m of gob was increased. This was caused by the higher resistance of the inbye section of the longwall (low resistance leakage paths through the gob are replaced by compartively high resistance paths).

In the final survey a feature not seen in previous measurements was noted close to the face. The airflow in the return gateroad was

reduced in the 150 m leading up to the face. Air is thought to have come from off the face because of a change in the type of pack used on the return gateroad gobside. This had allowed air to short circuit the return end of the face.

The profiles shown in Figure 10 represent measurements made whilst shotcrete was being sprayed onto the surface of the wooden packs along the first 400 m of intake gateroad.

The profile line marked 'A' was measured after the first 200 m of the intake had been coated with shotcrete. The improvement in the gob leakage through the first 200 m section is clearly evident when comparing the profile to 'B' which is the predicted curve for the leakage with no leakage prevention in place. This was calculated from a survey conducted four weeks previously before the shotcete was applied. A similar survey three weeks later produced profile 'C'. By this time the shotcrete had been applied to the 200 m to 400 m inbye section of the gateroad. The improvement in the leakage through this area of gob is noticeable, but what is interesting is the apparent deterioration in the sealing performance of the original shotcrete section from 0 to 200 m inbye. It is presumed that as the shotcrete dries out it shrinks and begins to take load from the strata causing cracking to occur, thus allowing more air leakage. This theory was further substantiated by the next survey performed two months later. The results of this, shown by profile 'D', indicate that the leakage in the 0 m to 400 m section of gob had again increased to a level almost equaling the original amount prior to the shotcrete application.

Figure 11 is a plot showing the calculated gob corridor resistance values for 9E compared to the gob corridor resistances of 8E and 4W. Although erratic it is easy to see that the gob corridor resistance of the monolithic packing lined gob (2000 NS^2/m^8) is nearly ten times the values for the conventionally packed areas (200 NS^2/m^8) in both 8E and 9E Longwalls.

5. CONCLUSIONS

Lining the intake gateroad of 9E with a thin layer of shotcrete effected a small reduction in the air leakage through the gob. This benefit was, for the most part, temporary; the sealing effect of the shotcrete lessened as it dried out and cracked due to strata movement.

Monolithic packing has proved far more effective at reducing gob leakage. The addition of the pumped pack has on average increased the gob corridor resistance by 1000 percent whilst maintaining the support. It has been demonstrated through computer simulations that if monolithic packing is used to make the intake gateside pack, it should be possible to complete 10E Longwall without utilising cundy ventilation.

6. ACKNOWLEDGEMENTS

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